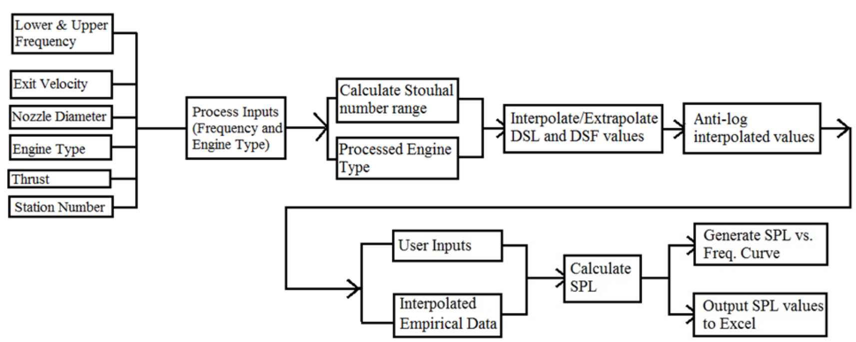
Acoustics Research of Propulsion Systems

Acoustical Society of America
October 28, 2014

Ximing Gao
Janice Houston

Objective

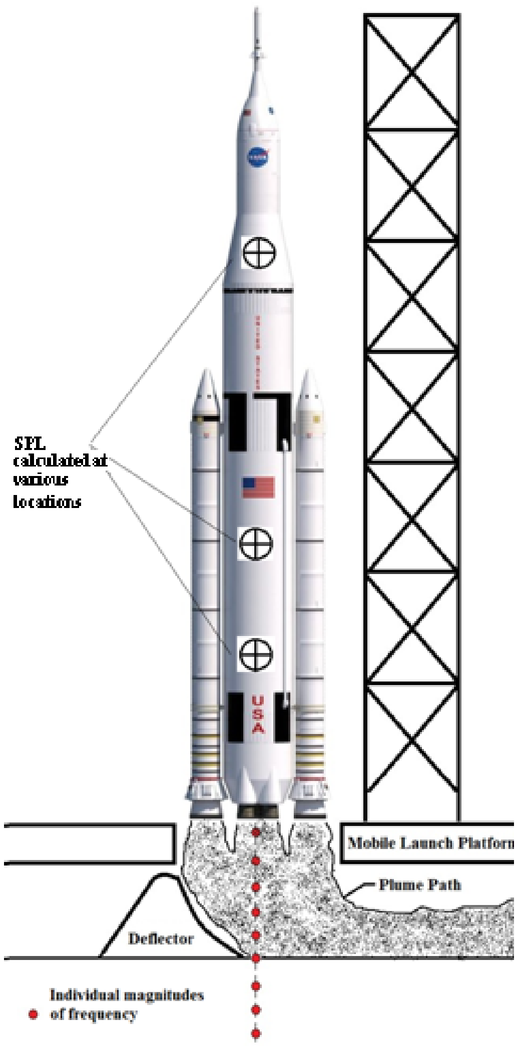
- **Launch vehicles are subjected to major acoustic loading at lift off**
  - Can result in malfunctions of mechanical or electronic components as well as structural fatigue
- **Acoustic loading predictions are imperative in determination of vibration design criteria**
- **Create the Prediction of Acoustic Vehicle Environments (PAVE)**
  - User Friendly GUI capable of 1-D lift off sound pressure level (SPL) predictions at up to 5 separate vehicle station locations simultaneously

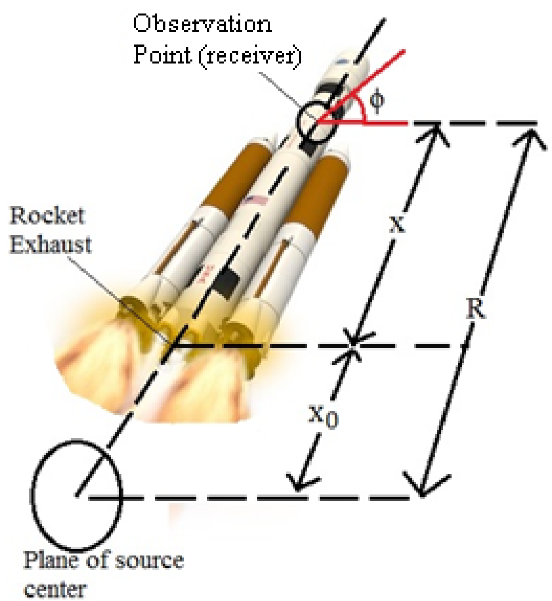


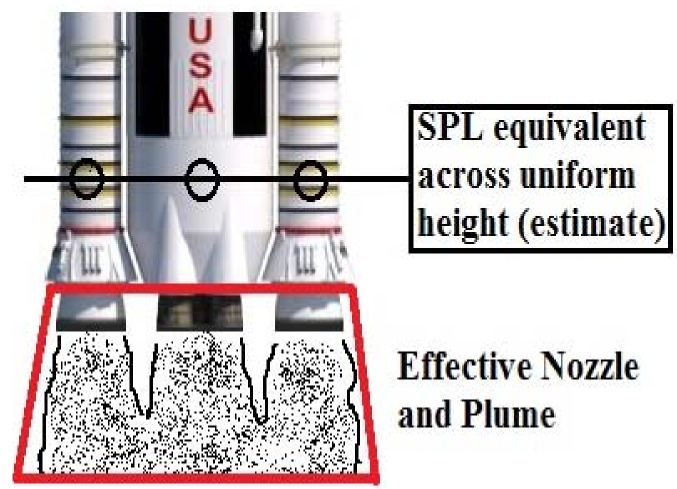
  - Ares I-X flight data used to create Dimensionless Spectrum Function (DSF) curves generated for a simulated hold down phase and entire launch phase

Method of Prediction

- 1-D environment assumed
- "Apparent" acoustic sources set in a single vertical axes
- SPL dependent on the sum R, of the station number X and the distance from the nozzle to the noise source X_0 (dependent on Dimensionless Source Location)
- Engine clusters defined by a single "effective" diameter





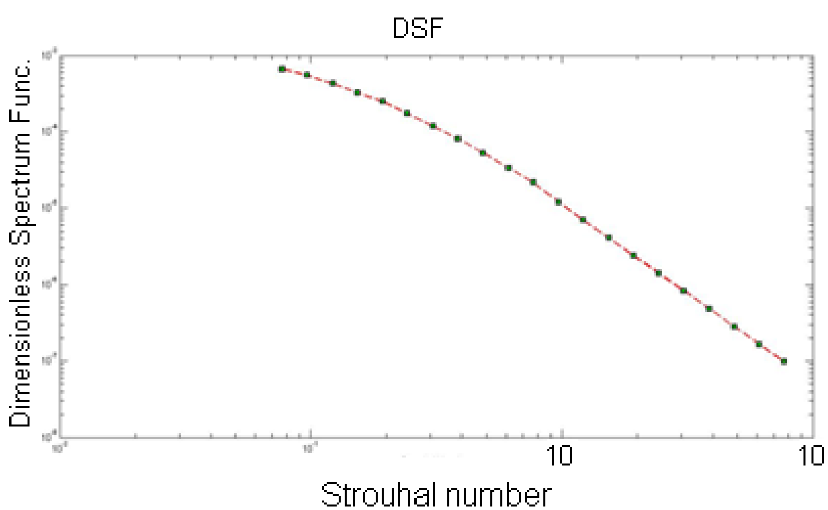


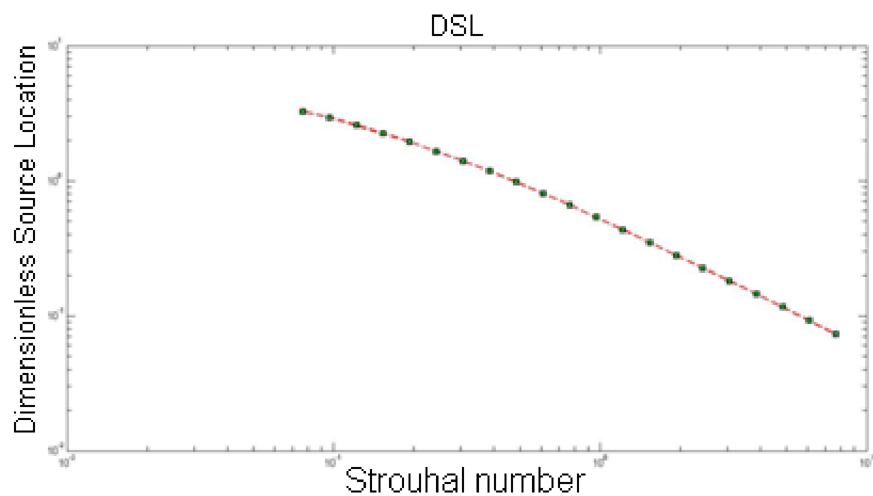
DSF and DSL Parameters

- Empirical Data: Until Ares I-X, static firing data
  - Example: J-2
- Dimensionless Spectrum Function (DSF):
  - Form of spectrum density proportional to sound power
- Dimensionless Source Location (DSL):
  - Defines distance from source to receiver (inversely proportional to Strouhal number)

Static Firing Test Stand at MSFC
(No Side Deflector or Water System)

Examples: J-2 engine DSF and DSL for frequency range of 20-2000 Hz



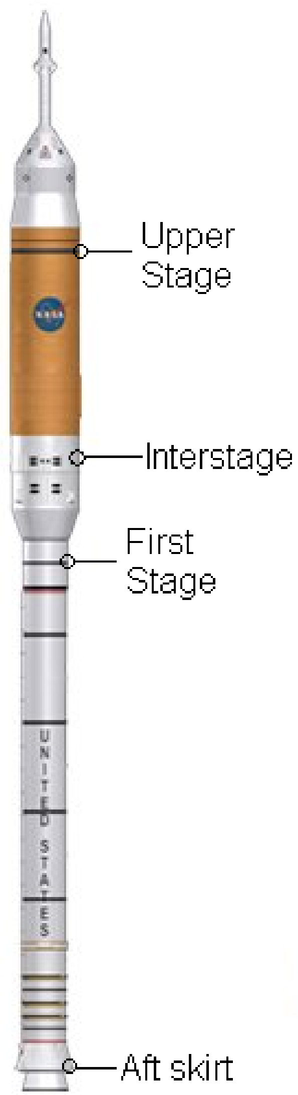


Ares I-X

- Launch Date: October 28, 2009, time 11:30 EDT
- Height: 327 ft.
- Thrust (Sea Level): 2,572,653 lbf
- Short Lift off Time: 5-6 sec.
- Instrumented with pressure transducers to measure acoustic environments

Ares I-X liftoff

Flight Instrumentation and Data Processing



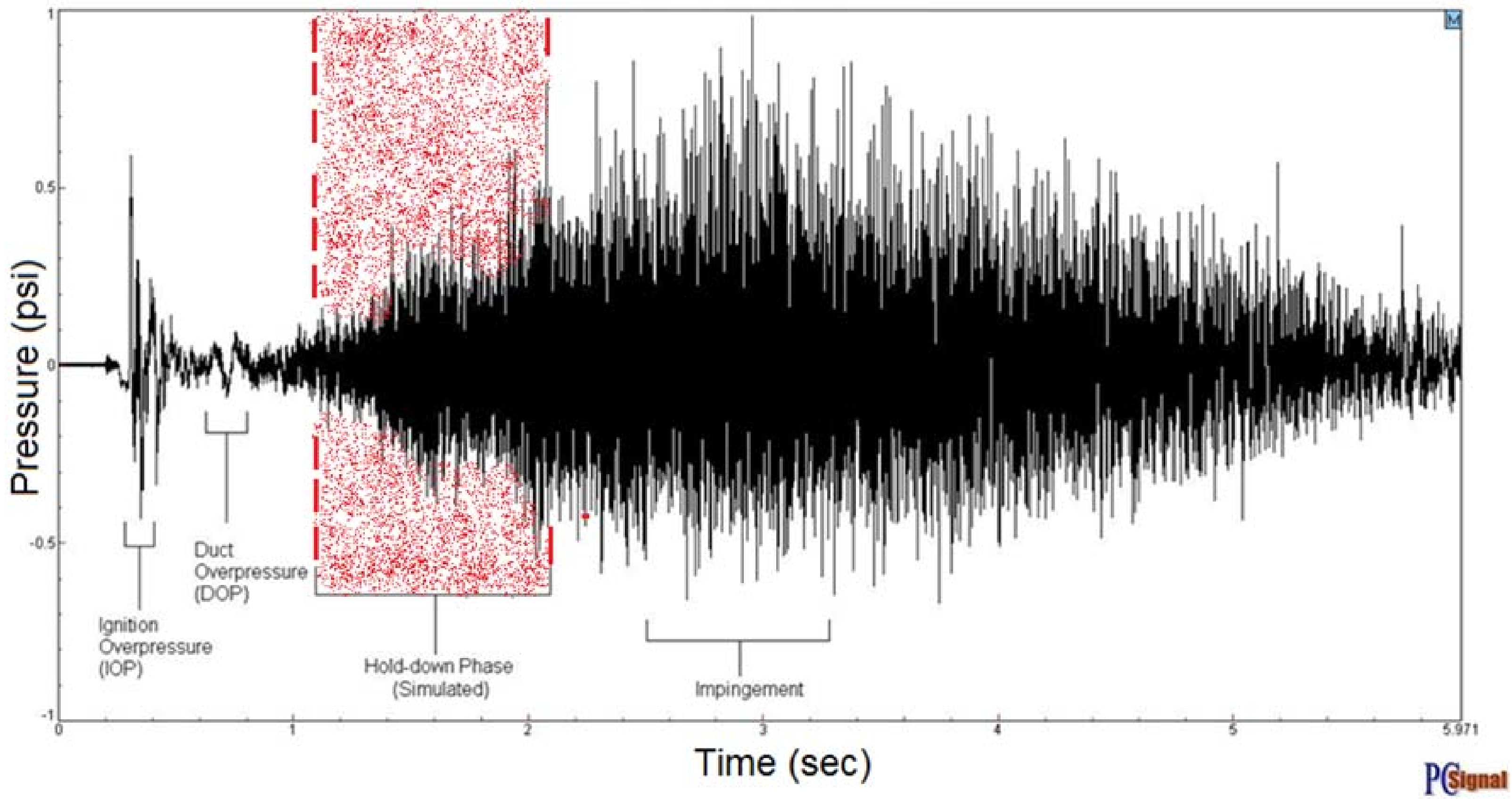
General placement locations of transducers

- Sensors set at sampling rates
  - 10417 sps
  - 5208 sps
- Raw Data form measured in pressure (psi)
- Data processed in two forms:
  - Simulated hold-down phase (paper)
  - Launch phase
- All relevant channels processed and four selected based on data quality and position

Data Processing: Time History

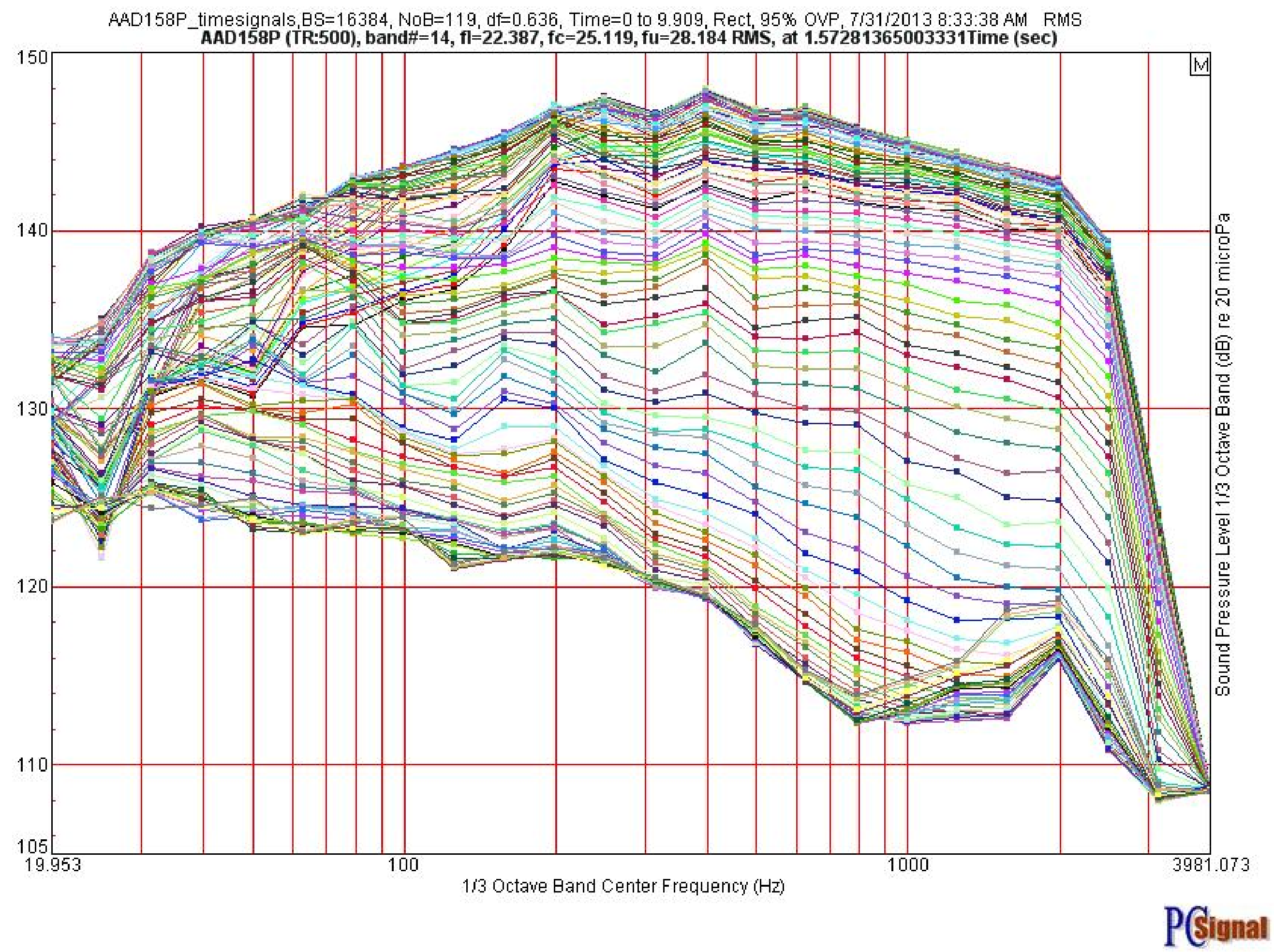
- Time history of data created for each individual sensor

Time history of acoustic events at liftoff (aft skirt region)



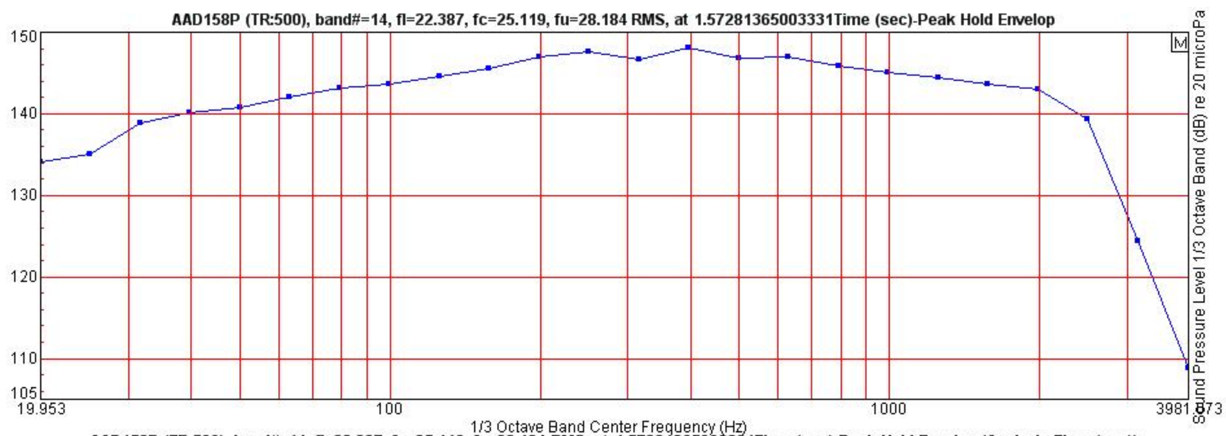
Data Processing: Liftoff

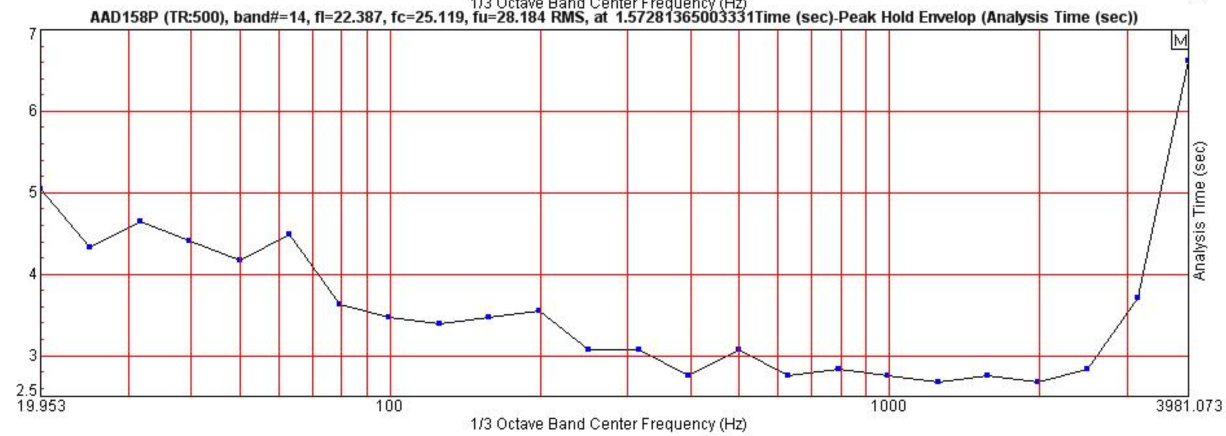
- All frequencies peak at different times
- Analysis requires an overall maximum accounting for all frequencies irrespective of time



Data Processing for Liftoff: Peak Hold Spectrum

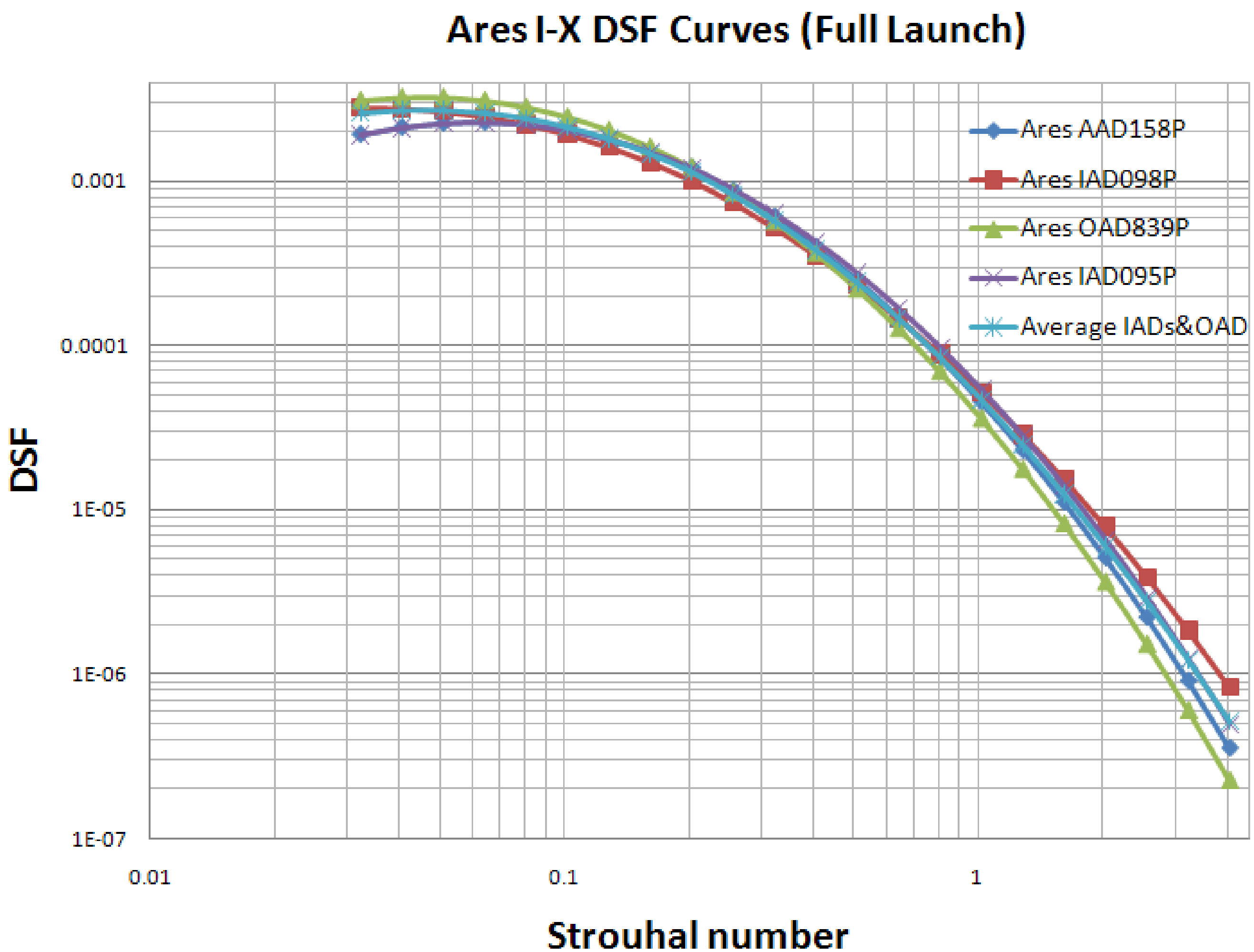
- Defines the maximum SPL value for each 1/3 Octave Band irrespective of time
  - Considered an “artificial” spectra that includes the worse cases: Suitable for design purposes





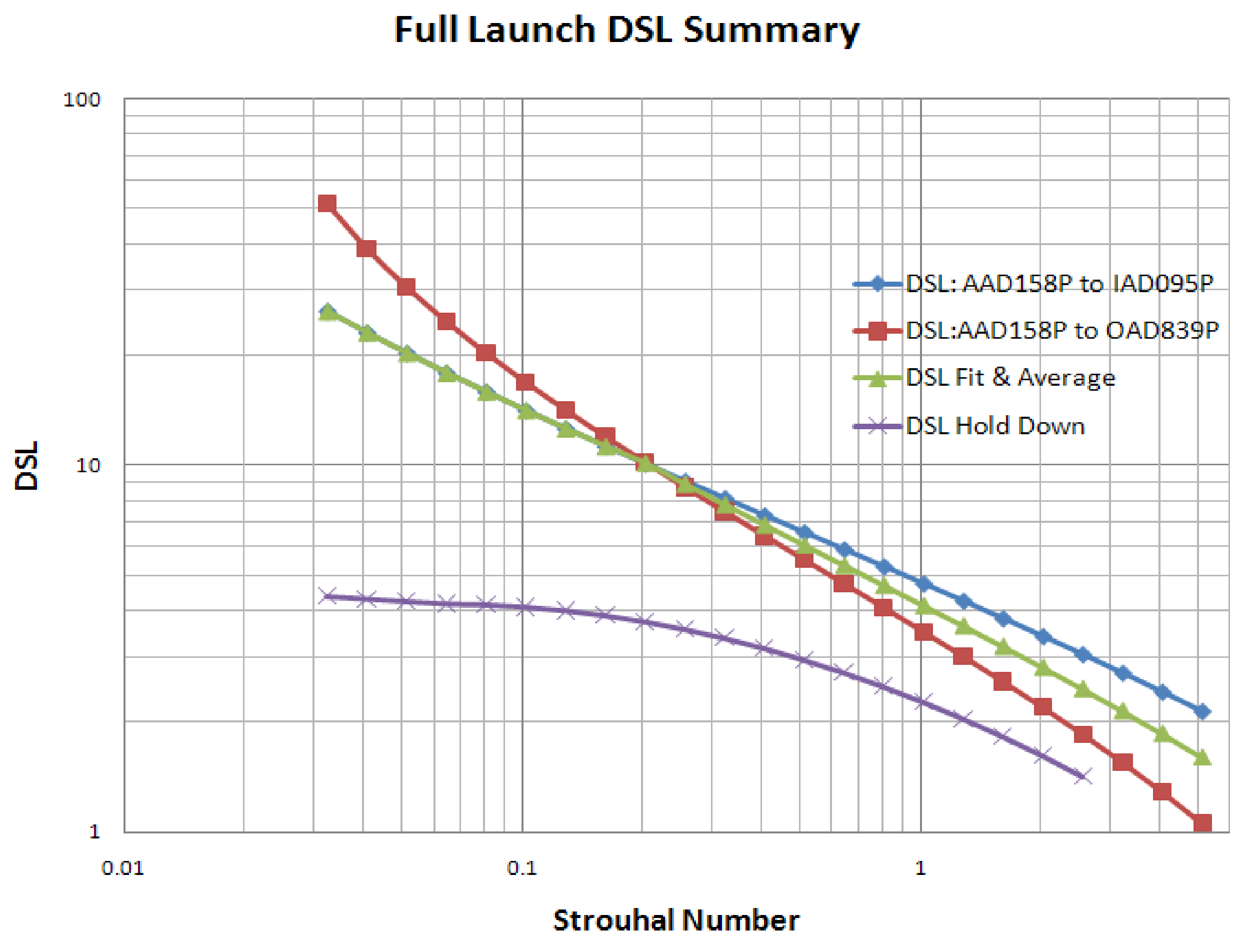
DSF Curve Generation for Liftoff

- Consistency maintained along curves allowing for smooth average



DSL Curve Generation for Liftoff

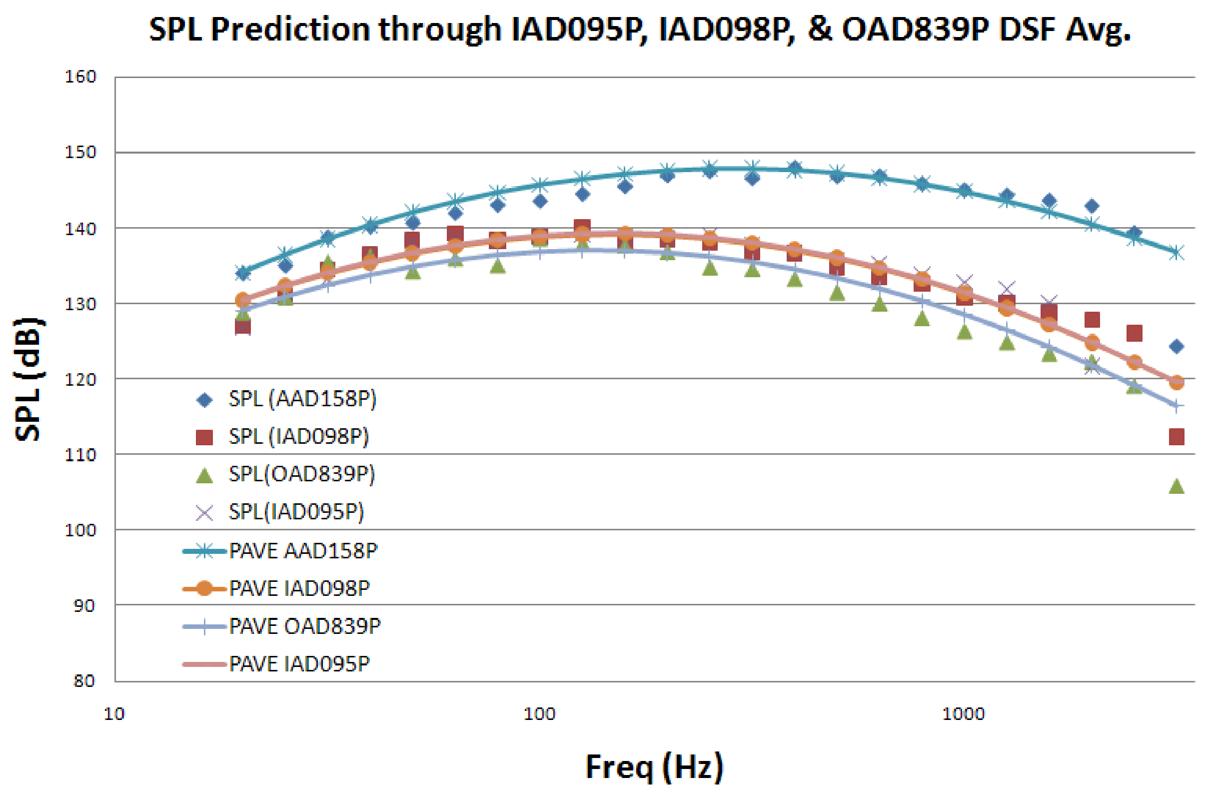
- Consequence of randomness in time ranges when obtaining peak hold spectra; ranged from 1 to 51



Generated DSF Accuracy for Liftoff

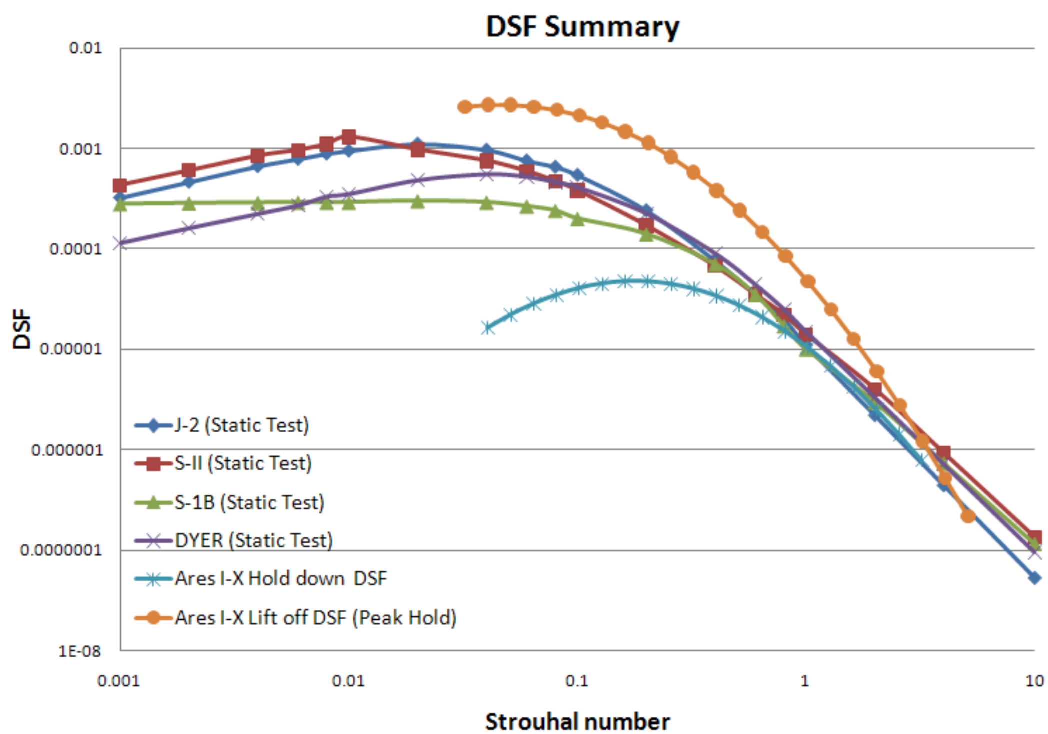
- Relatively smooth predictions for all sensors
- Average Delta Calculated (Predicted-Raw)

Sensor	Average Delta dB
AAD158P	*0.97*
IAD098P	*1.24*
OAD839P	*1.20*
IAD095P	*1.06*

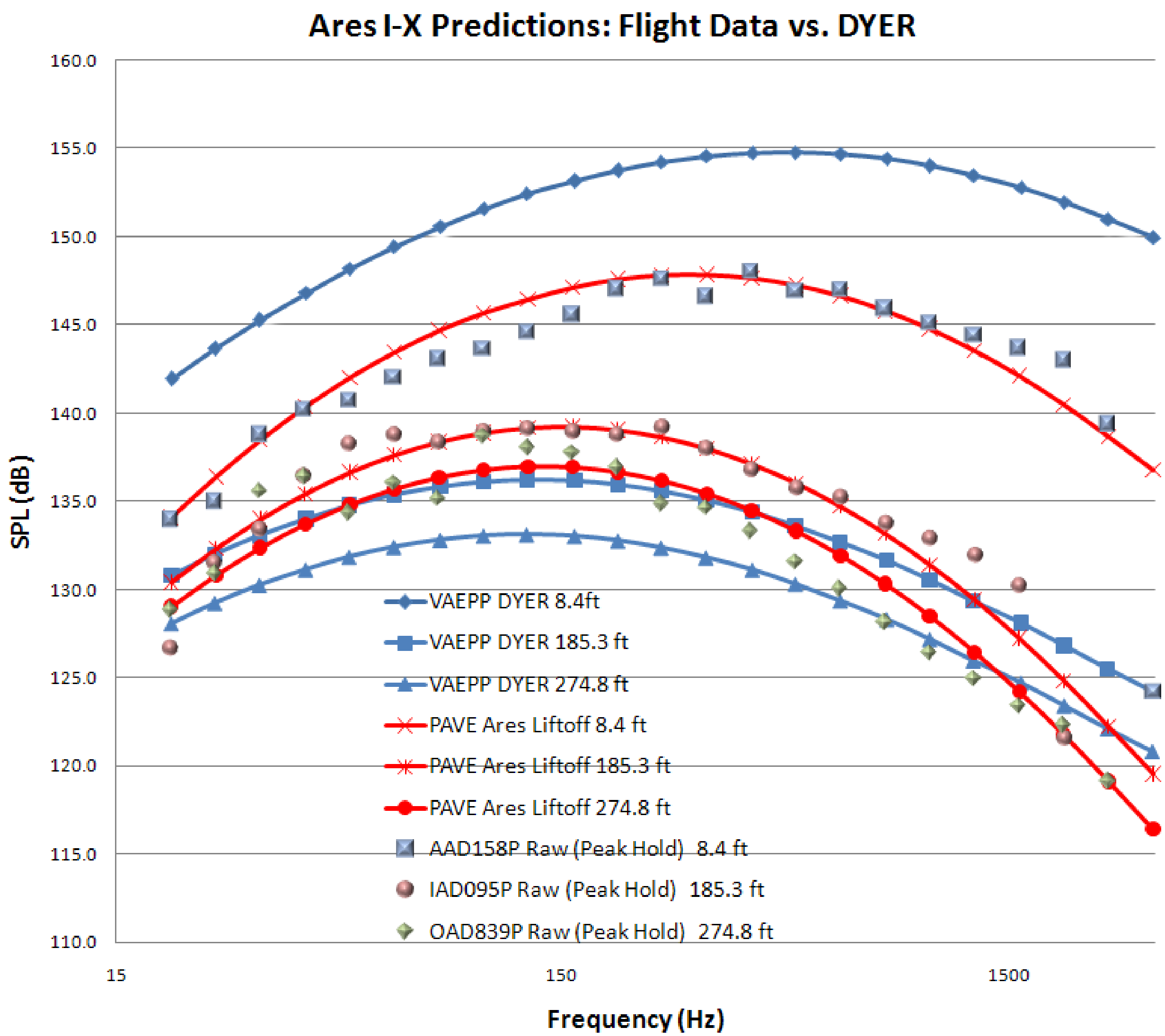


Overall DSF Comparison

- Static tests conducted in different environments with virtually no water suppression
- Hold down DSF considered an “isolated” time frame where water suppression influence is significant
- Peak Hold DSF shows highest values due to structure of maximum SPL’s selected from each frequency and impingement effects



PAVE SPL Predictions: Flight Data vs. DYER vs. Ares I-X



Conclusions

- **Acoustic SPLs measured from flight data significantly differ from those of static firings**
- **The Ares I-X flight data results in a much narrower range of DSF values when compared to static firings**
  - Possibly due to the differences in launch pad configurations
- **Flight data can be accurately reproduced and scaled: the use of flight data can lead to more accurate predictions in acoustic loads for future launch vehicles such as Space Launch System (SLS)**